REMARKS

The above amendments to the specification, claims and abstract have been made to place the application in proper U.S. format and to conform with proper grammatical and idiomatic English. None of the amendments herein are made for reasons related to patentability. No new matter has been added.

Attached hereto is a marked up version of the changes made to the specification, abstract, and claims by the current amendment. The attached is captioned "**Version with markings to show changes made**".

In the event that the transmittal letter is separated from this document and the Patent Office determines that an extension and/or other relief is required, applicant petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 501871** referencing docket number P1999,0003USN. However, the Commissioner is NOT authorized to charge the cost of the issue fee to the Deposit Account.

Respectfully submitted,

by: ______

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

For the convenience of the Examiner, the changes made are shown below with deleted text in strikethrough and added text in underline.

In the specification:

Page 1, between lines 4 and 5, has been amended to include the following heading:
-CROSS REFERENCE TO RELATED APPLICATIONS--.

Page 1, between lines 4 and 5 and after the above heading, has been amended to include the following insert:
This application claims priority to International Application No.: PCT/DE00/04089 which was published May 31, 2001. This application further claims priority to German patent application 19955747.0 filed 19 November 1999.

Page 1, between lines 5 and 6, after the above insert, has been amended to include the following heading:
BACKGROUND OF THE INVENTION.

Paragraph beginning on page 1, line 11 has been amended as follows:
A device of this type is known for example from EP 0 666 624 B1 or from the Journal of Crystal Growth 189/190 (1998) pages 786-789.

Page 2, between lines 18 and 19, has been amended to include the following heading:
SUMMARY OF THE INVENTION.

Paragraph beginning on page 2, line 19, has been amended as follows:
~~The~~ It is an advantage of the present invention ~~is based on the object of improving in this respect an~~ to improve the optical semiconductor device set out above ~~of the type stated at the beginning~~.

Paragraph beginning on page 2, line 23, has been amended as follows:

The present invention achieves this ~~object by the feature of patent claim 1~~ and other advantages through an optical semiconductor device with a multiple quantum well structure, comprising: at least one combination of alternating well layers and barrier layersboth further comprising various semiconductor layers, said well layers further comprising a first composition based on a nitride semiconductor material with a first electron energy, said barrier layers further comprising a second composition of a nitride semiconductor material with electron energy which is higher in comparison with the first electron energy, and a radiation-active quantum well layer, layered in direction of growth for which the well layers and barrier layers form a superlattice.

Paragraph beginning on page 2, line 26, has been amended as follows:
The invention provides a multiple quatum well structure with well layers and barrier layers comprising various types of semiconductor layers which are layered alternatively one on top of the other. ~~in which the~~ The well layers are thin layers of a first composition based on a nitride semiconductor material with a first electron energy~~, and the~~. The barrier layers are layers which are thicker in comparion to the well layers, are of a second composition of a nitride semiconductor material and are with electron energy which is higher in comparison with the first electron energy. Acting as the radiation-active quatum well, seen in the direction of growth, is firstly one of the last quatum well layers or the last quatum well layer. The well layers arranged in front, which essentially do not radiate, and the barrier layers form a superlattice for this last layer.

Paragraph beginning on page 3, line 5, has been amended as follows:
~~In a particularly preferred development~~ According to an embodiment of the invention, in the superlattice, the well layers are thin aluminum-gallium-indium-nitride layers, ~~and~~ the barrier layers are gallium-nitride layers which are thicker in comparison, and the active quantum well has indium-gallium-nitride.

Paragraph beginning on page 3, line 19, has been amended as follows:
In a particularly preferred development, at least one of the well layers of the superlattice has at least one pair of single layers, of which the first single layer, in the direction of growth, has a lower indium content than the second single layer. ~~in the direction of growth.~~ This well layer preferably has a plurality of single layers whose indium content increases step by step from the single layer lying furthest away from the radiation-active quantum well layer to the

single layer lying closest to the radiation-active quantum well layer. It is particularly preferred for the steps of the increase in indium content to be smaller than 5%. It is also ~~particularly~~ preferred for the indium content of the single layer furthest away from the radiation-active quatum well layer to be less than 5%. The thickness of the single layers preferably lies in the range of just a few monolayers~~,~~ and particularly preferably approximately one monolayer.

Paragraph beginning on page 3, line 38, has been amended as follows:
The particular advantage of the step-by-step increase in the In content is that a potential profile resembling a delta potential is produced, in particular in the case where the thickness of the single layers does not significantly exceed that of a monolayer. The difference in the energy level in the barrier layers and the energy level obtained for one electron in the well layer is consequently not greater than~~,~~ in the case of a rectangular well layer with a significanly lower indium content as the uppermost single layer of the stepped well layer. ~~This achieves the effect that~~ Accordingly, the advantages of a reduced overall indium content are retained, but the strain is at the same time influenced by the high indium content of the last single layer in such a way that the nucleartion of InGaN-rich phases is improved and, consequently, the quantum efficiency is increased.

Page 5, between lines 14 and 15, has been amended to include the following new heading:
BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS.

Paragraph beginning on page 5, line 19, has been amended as follows:
Figure 1a~~,~~ and 1b show~~s~~ a schematic representation of the layer structure of a device according to the invention,

Page 5, between lines 32 and 33, has been amended to include the following new heading:
DETAILED DESCRIPTION OF THE INVENTION.

Paragraph beginning on page 5, line 33 has been amended as follows:
According to figure 1a, initially a buffer layer 3 of aluminum-gallium-nitride (AlGaN) is formed on a substrate 1 of silicon carbide (SiC), to which a first contact electrode 2 is connected. This is followed by a further layer 4 of aluminum-gallium-nitride. A further buffer layer 5 of silicon-doped gallium nitride is arranged over the layer 4. ~~and the~~ The

quantum well structure 6a, 6b, still to be ~~explained~~ discussed in more detail, is arranged over ~~that,~~ buffer layer 5. Quantum well structure 6a and 6b are followed by the actual active layer 6c. Arranged over the active layer 6 is a further layer 7 of aluminum-gallium-nitride, which serves as an electron barrier. This layer 7 is preferably doped with magnesium. A further GaN layer, not designated, may be arranged between the layers 6 and 7. A gallium-nitride layer 8, on which a second contact electrode 9 of the device is provided, is arranged over the layer 7.

Paragraph beginning on page 6, line 18, has been amended as follows:
The buffer layer 3 functionally serves as a growth layer, which is required to allow the LED structure to grow on the silicon carbide substrate 1. The further aluminum-gallium-nitride layer 4, between the layers 3 and 5, has an aluminum content which changes in the direction of the gallium-nitride layer 5. The gallium-nitride layer 5 is preferably silicon doped. The layer 7 of magnesium-doped aluminum-gallium-nitride, arranged over the active layer 6, serves as an electron barrier.

Paragraph beginning on page 6, line 28, has been amended as follows:
This basic structure of figure 1a can be used as a standard for gallium-aluminum-indium-nitride light-emittind diodes (LEDs).

Paragraph beginning on page 7, line 13, has been amended as follows:
The indium content lies below 24%, preferably however below 20%, and is therefore preferably reduced in comparison with customary indium contents. The layers 6a and 6b, depicted only once in the figure, may be arranged repeatedly one above the other~~, the structure preferably being.~~ The layers may be structured repeatedly x=3 times. The uppermost gallium-nitride layer 6b is followed by the actually active, i.e. illuminating, layer 6c of indium-gallium-nitride.

Paragraph beginning on page 8, line 4, has been amended as follows:
The use according to the invention of GaInN/GaN superlattices with thin wells (to a quantum well width of approximately 2 nm) in a layer structure according to figure 1 and with quantum well conditions according to figure 2 allows the forward voltage to be significantly lowered and, at the same time, the high internal quatum efficiency of the indium-gallium-nitride based optical semiconductor device to be maintained. The piezo fields, otherwise form~~ing~~ed, are

avoided entirely or have virtually no effect any longer. In comparison with customary single quantum-well structures, in which no gallium-indium-nitride superlattice is deposited before the active well, the device structure according to the invention has twice the conversion efficiency.

In the claims:

The claims have been amended as follows:

1. An optical semiconductor device with a multiple quantum well structure, comprising: at least one combination of alternating ~~in which~~ well layers and barrier layers~~,~~ both further comprising various ~~types of~~ semiconductor layers ~~are alternately layered~~, ~~in which device~~said well layers further comprising ~~(6a) of~~ a first composition based on a nitride semiconductor material with a first electron energy, ~~and~~ said barrier layers ~~(6b)~~further comprising ~~of~~ a second composition of a nitride semiconductor material with electron energy which is higher in comparison with the first electron energy ~~are provided, followed, seen in the direction of growth, by~~, and a radiation-active quantum well layer ~~(6c)~~, layered in direction of growth for which the ~~essentially non-radiating~~ well layers ~~(6a)~~ and ~~the~~ barrier layers ~~(6b) arranged in front~~ form a superlattice.

2. The optical semiconductor device ~~as claimed in patent~~according to claim 1, ~~in which~~ wherein the well layers ~~(6a) are~~ comprise thin aluminum-indium-gallium-nitride layers and the barrier layers ~~(6b) are~~ comprise gallium-nitride or aluminum-gallium-nitride layers which are thicker ~~in comparison~~ than the well layers and the radiation-active quantum well ~~(6c) is~~ comprises an indium-gallium-nitride layer.

3. The optical semiconductor device ~~as claimed in patent~~ according to claim 1 ~~or 2, in which~~, wherein the radiation-active quantum well ~~(6c)~~ follows ~~the~~ an uppermost barrier layer ~~(6b)~~.

4. The optical semiconductor device ~~as claimed in one of~~ according to ~~patent~~ claims 1 ~~to 3~~, ~~in which the~~ wherein layer thickness of the radiation-active quantum well ~~(6c)~~ is greater than ~~the~~ layer thickness of the well layers ~~(6a)~~ of the superlattice.

5. The optical semiconductor device ~~as claimed in one of patent~~ according to claims 1 ~~to 4~~, ~~in which~~ wherein the well layers ~~(6a)~~ are thinner than 2 nm and the barrier layers ~~(6b)~~ are are at least 3 nm thick ~~or thicker~~.

6. The optical semiconductor device ~~as claimed in one of patent~~ according to claims 2 ~~to 5~~, ~~in which~~ wherein the well layers and barrier layers ~~(6a, 6b)~~ are doped with silicon.

7. The optical semiconductor device ~~as claimed in patent~~ according to claim 6, ~~in which~~ wherein the dopant concentration is from 10^{17} to 10^{18} cm^{-3}.

8. The optical semiconductor device ~~as claimed in one of patent~~ according to claims 1~~-to 7~~, ~~in which,~~ wherein within at least one well layer ~~(6a)~~ of the superlattice, the In content increases in ~~the~~ a direction of growth.~~, i.e. in the direction of the radiation-active quantum well layer (6c).~~

9. The optical semiconductor device ~~as claimed in~~ according to claim 8, ~~in which,~~ wherein in the well layer ~~(6a),~~ the indium content, remote from the ~~radiation-active~~ quantum well layer, lies below 5%.

10. The optical semiconductor device ~~as claimed in one of~~ according to patent claims 1~~-to 7~~, wherein ~~in which~~ at least one of the well layers ~~(6a)~~ of the superlattice has at least one pair of single layers ~~(60a, 61a),~~ of which ~~the~~ a first ~~single layer (60a)~~of the at least one pair, in ~~the~~ a direction of growth, has a lower indium content than ~~the~~ a second ~~single layer (61a)~~of the at least one pair in ~~the~~ a direction of growth.

11. The optical semiconductor device ~~as claimed in~~ according to claim 10, ~~in which~~ wherein the second ~~single layer (61a)~~of the at least one pair has an increased indium content ~~higher by~~of less than 5% ~~than~~ of the first ~~single layer (60a)~~of the at least one pair.

12. The optical semiconductor device ~~as claimed in~~ according to claim 10 ~~or 11 in which~~wherein the well layer ~~has~~ comprises a plurality of single layers ~~(60a, 61a, 62a, 63a)~~ whose indium content increases ~~step by step~~ from ~~the~~ a first of the plurality of single layers ~~(60a)~~ lying furthest away from the ~~radiation-active~~ quantum well layer ~~(6c)~~ to ~~the~~ a single layer ~~(63a)~~ lying closest to the radiation-active quantum well layer ~~(6c)~~.

13. The optical semiconductor device ~~as claimed in~~ according to claim 12, ~~in which~~ wherein the indium content ~~steps of the~~ increase ~~in the indium content are~~ is smaller than 5%.

14. The optical semiconductor device ~~as claimed in one of~~ according to claims 10 ~~to 13~~, ~~in which~~ wherein the indium content of the first of the at least one pair of single layers ~~(60a) lying furthest away from the radiation-active quantum layer (6c)~~ is less than 5%.

15. The optical semiconductor device ~~as claimed in one of~~ according to claims 10 ~~to 14~~, ~~in which the~~wherein a thickness of each of the plurality of single layers ~~(60a, 61a, 62a, 63a) lies in the range of just~~comprises ~~a few~~ at least one monolayers. ~~or corresponds approximately to one monolayer.~~

16. The optical semiconductor device according to claim 10, wherein a thickness of each of the plurality of single layers comprises approximately one monolayer.

17. The optical semiconductor device according to claim 2, wherein the radiation-active quantum well follows an uppermost barrier layer.

18. The optical semiconductor device according to claim 2, wherein layer thickness of the radiation-active quantum well is greater than layer thickness of the well layers of the superlattice.

19. The optical semiconductor device according to claim 2, wherein the well layers are thinner than 2 nm and the barrier layers are are at least 3 nm thick.

20. The optical semiconductor device according to claim 3, wherein the well layers and barrier layers are doped with silicon.

21. The optical semiconductor device according to claim 2, wherein within at least one well layer of the superlattice, the In content increases in a direction of growth.

22. The optical semiconductor device according to patent claim 2, wherein at least one of the well layers of the superlattice has at least one pair of single layers of which a first of the pair, in a direction of growth, has a lower indium content than a second of the pair in a direction of growth.

23. The optical semiconductor device according to claim 11 wherein the well layer comprises a plurality of single layers whose indium content increases from a first of the plurality of single layers lying furthest away from the quantum well layer to a single layer lying closest to the radiation-active quantum well layer.

24. The optical semiconductor device according to claim 11, wherein the indium content of the first of the pair of single layers is less than 5%.

25. The optical semiconductor device according to claim 11, wherein a thickness of each of the plurality of single layers comprises at least one monolayer.

In the Abstract:

Paragraph beginning on line 7, page 14, has been amended as follows:

An optical semiconductor device with a multiple quantum well structure~~,~~ is set out in which well layers and barrier layers, comprising various types of semiconductor layers, are alternately layered. ~~in which~~ The device well layers ~~(6a) of~~ comprise a first composition based on a nitride semiconductor material with a first electron energy. ~~and~~ The barrier layers ~~(6b) of~~ comprise a second composition of a nitride semiconductor material with electron energy which is higher in comparison ~~with~~ to the first electron energy. The well and barrier layers are ~~are provided, followed, seen~~ in the direction of growth, by a radiation-active quatum well layer ~~(6c), for~~ which with the essentially non-radiating well layers (6a) and the barrier layers (6b), arranged in front, form a supperlattice.

The paragraph of line 22, page 14, has been deleted.